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PORTRAIT OF A PROGRAM - THE DART-TYCOM 400 HZ MOTOR GENERATOR P--ETC(U)
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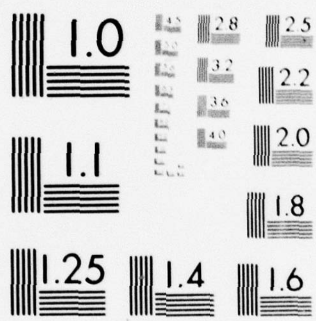

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PORTRAIT OF A PROGRAM - THE DART-TYCOM 400 HZ MOTOR GENERATOR POWER SYSTEMS IMPROVEMENT PROGRAM

(10) Alfred P. Nickley

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THE DART-TYCOM 400 HZ MOTOR GENERATOR
POWER SYSTEMS IMPROVEMENT PROGRAM

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Naval Ship Engineering Center
March 1977

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AUTHOR

Upon graduation from Case Institute of Technology in 1953 with a Bachelor of Science Degree in Electrical Engineering, Mr. Alfred P. Nickley began his career in industry as a motor design engineer. In 1959, he accepted the position of electrical engineer in the Motor and Motor-Generator Section of BUSHIPS where he was the cognizant engineer in charge of all Navy motors. From 1967 to 1972, Mr. Nickley served as the electrical engineer for the Supervisor of Shipbuilding, Bath, England. In this position, he provided guidance in all electrical matters to the United Kingdom shipbuilders during the design, construction and testing of two oceanographic research ships and three ocean going salvage tugs built in the United Kingdom in accordance with Navy specifications. After completion of his tour of duty, he joined NAVSEC and is currently a project engineer with technical cognizance for all surface ship 400-Hz motor-generators. For the past four years, he has served as NAVSEC program manager for the DART-TYCOM 400-Hz Motor-Generator Improvement Program in addition to his regular duties.

ABSTRACT

The success or failure of any equipment improvement program must be measured in terms of the ultimate benefits derived by the fleet and whether the resultant benefits were worth the time, effort and funds expended. In consideration of this criteria, the DART-TYCOM 400-Hz Motor-Generator Power Systems Improvement Program must be deemed a success. The Program was developed by the Naval Ship Engineering Center (NAVSEC) in mid 1971 to combat the numerous casualties and excessive downtimes experienced by the 400-Hz power systems supplying critical loads onboard U.S. Navy surface ships. By concentrating its effort over the next four and one-half years in five major areas - logistics support, hardware reliability, training, Fleet support and power/user equipment systems interface - the Naval Ship Engineering Center was able to effectively increase the on-line availability of the 400-Hz motor-generator power systems.

INTRODUCTION

In early 1971, the sins of our fathers were visited upon us; the pigeons came home to roost; the poor camel was hit with the last straw and the house was coming down around our heads. You name the cliche' and it could be applied to the 400-Hz motor-generator power systems on board our surface ships. The Fleet was being plagued with numerous casualties and excessive downtime of 400-Hz motor-generator sets supplying critical ship's loads.

This paper describes the response of the Naval Ship Engineering Center to a multi-faceted problem. Specifically, the development of the DART-TYCOM 400-Hz Motor-Generator Power System Improvement Program; the establishment of objectives; the determination of program scope and, most importantly, the multiple achievements reflected in tangible benefits to the operating Fleet.

BACKGROUND

Before we get involved in the details of the program, we had better identify just what it is that we are improving. For purposes of this paper, we will define a 400-Hz motor-generator power system as one composed of one or more 400-Hz motor-generator sets, the ancillary switchgear and the load. Wherever the term motor-generator set is used, read - motor-generator and associated control equipment.

Very briefly, a 400-Hz motor-generator is a two bearing, rotating unit that converts 60-Hz input power, supplied to the motor, to 400-Hz output power through the action of the generator. Of course, a motor-generator system isn't quite that simple; otherwise, there wouldn't have been the multitude of problems. The complications arise when the control equipment is applied to the rotating unit. A high percentage of today's shipboard motor-generator sets are controlled by both a voltage and frequency regulator to maintain the output voltage and frequency to within plus or minus 0.5 percent of rated value. Add further restrictions on the output, such as fast recovery time, wave shape, harmonic content, etc., and you have a pretty complicated gadget. Figure 1 illustrates a typical voltage and frequency regulated motor-generator set; all control systems are completely solid-state, utilizing large silicon controlled rectifiers in the power handling circuits. The seemingly simple matter of keeping track of the major components that make up a specific motor-generator set is actually a horrendous task. There are over 1200 major component units making up over 195 motor-generator systems!

The situation is further complicated by the multiplicity of equipment designs. An extreme example is the case of one contractor who provided more than ten different versions of one motorgenerator set rating. While this is certainly a very undesirable state of affairs, there are several good reasons for it.

In the first place, the procurement specifications are performance type wherein the performance and materials are controlled, but not the specific design. Secondly, existing procurement policies prohibit sole-source procurements except under certain specific circumstances as governed by the Armed Services Procurement Regulations. This means that you generally cannot reprocure from a certain manufacturer with a proved design simply to promote standardization. The majority of procurements are advertised and contracts awarded to the lowest conforming bidder. Thirdly, over the years, NAVSEC has been unable to obtain funds for development of a series of standard designs. Unless the Navy has unlimited rights to a set of manufacturing drawings, standardization is impossible.

The result is a proliferation of equipment designs, some good, some bad, which has a far reaching, adverse effect on logistics, training, reliability, maintainability and documentation.

INITIATION OF PROGRAM

While the Naval Ship Engineering Center has long recognized that a 400-Hz motor-generator improvement program was sorely needed, corrective actions had to be taken on a case basis due to the lack of funds available for an in-depth study of 400-Hz problems and their subsequent correction.

Help arrived in mid 1971. 400-Hz motor-generator sets were identified as a DART-TYCOM item, designated a Chief of Naval Material Red Ball Project and funding was made available by the Naval Sea Systems Command. There was now a program; it was up to NAVSEC to produce.

The first order of business was to establish the major problem areas. What really was the trouble? To this end, NAVSEC conducted a detailed study of Maintenance Data Collection Subsystems reports, casualty reports ship repair reports and NAVSEC field activity trip reports covering the previous three years. This initial investigation revealed the following underlying causes:

- Many of the motor-generator sets were approaching or had exceeded their life expectancies.

- Specific design deficiencies.

- Poor logistics support.
- Inadequate technical documentation
- Lack of personnel training.
- Power/user equipment interface problems.

With this "first cut" in hand, the primary objective of the program took shape - to increase the 400-Hz motor-generator power system on-line availability by improving: logistics support, hardware reliability, training, Fleet support and power/user equipment system interface. To achieve this objective, an improvement program composed of eleven major milestones was established (see Figure 2). Several of these milestones were further sub-divided, resulting in a total of 49 major program elements; each of which required a funding estimate, a date of projected completion and, equally as important, consideration as to how the work was going to be accomplished.

It was estimated that the entire program would cost approximately 11 million dollars and would run for a period of four years. This was not to be. As time went on, the amount of funding made available steadily decreased in spite of the yoeman efforts of the Naval Sea Systems Command to maintain the planned funding level. The Chief of Naval Material had other dragons to slay and the cost of mounting such expeditions had to come from somewhere. So, reprogramming was necessary. In the end, our total funds were cut to 7.8 million dollars. As will be seen, however, the Naval Ship Engineering Center was still able to accomplish the primary program objective.

With each funding cut, all program elements were reviewed. Was this element absolutely necessary; what would it buy; could it be dropped? Could that element be curtailed; could it be stopped now and still get something worthwhile out of it, or should it be carried awhile longer and then terminated? Wherever possible, the hardware fix elements and those that impacted directly on the Fleet were retained. It was a drill run through many times to ascertain that the available funds were spent on those elements most likely to produce the greatest benefits.

From the very beginning, it was obvious that a program of this magnitude could not be pursued within the limited manpower resources of NAVSEC alone. At its inception, NAVSEC could muster only one program manager/engineer, one engineer on a part-time basis and one engineer-in-training. About a year and a half later, the two assistants were reassigned to other pressing duties and only the program manager was left. That was it for the remaining three years of the program. Of course, the assistance of other NAVSEC engineering codes could be drawn upon for specific tasks; but, here too, there was a limit on the amount of time and manpower that could be made available. Three options, then, were open - use contractors through existing Level of Effort (LOE) contracts, initiate new contracts, or task other naval activities.

An across the board use of LOE's was not feasible as the amount of services that could be purchased was limited and the "nuts and bolts" nature of much of the work was outside the scope of their contracts. Many of the manufacturers of the problem equipments were no longer interested in Navy business and several had gone out of business. Other naval activities could only provide limited assistance because of their own workload. The ultimate course taken was to utilize all three outside sources, so that we had one program manager directing the efforts of eight NAVSEC codes, thirteen contractors and twenty-two naval activities (see Figure 3). Not only directing, but allotting the funds, preparing the task statements, initiating the new contracts, reviewing proposed equipment redesigns, providing monthly status reports to NAVSEA and monitoring all programs.

As with any program of this breadth and scope, there were some failures. Failures inasmuch as what was attempted was proved impossible or impractical to accomplish. In the final analysis, however, the success or failure of any equipment program must be measured by its ultimate effect on the Fleet. What did it do for the Fleet; how did the Fleet benefit from all the time, effort and funds expended? By this yardstick, the DART-TYCOM 400-Hz Motor-Generator Power System Improvement Program must be scored a success. The primary objective was achieved. The 400-Hz motor-generator power system on-line availability has been increased as evidenced by a reduction in the downtime and the number of casualties experienced on program units. How this was accomplished in each of the major program improvement areas previously mentioned is outlined below.

LOGISTICS SUPPORT

An adequate and responsive logistics support program is essential to Fleet readiness. Without the necessary onboard/stock repair parts, excessive equipment downtime results while the parts are ordered by the ship, purchased by the stock facility, shipped, received and installed. Lack of a few repair parts can result in aborting of the ship's mission. Casualty reports and the subsequent situation reports are replete with extension of times to repair due to delay in receiving parts.

To remedy this situation, the Ships Parts Control Center, Mechanicsburg was tasked to review all 400-Hz motor-generator set Allowance Parts Lists (APL's). In the performance of this task, SPCC MECH identified over 195 unique motor-generator sets; each set made up of several APL's (motor-generator, voltage regulator, etc). Of a total of 1200 applicable APL's, some 1100 were reworked to add parts found to be lacking. Over 1700 new stock number parts were added and over 5000 formerly deleted parts were reinstated. All updated APL's were forwarded to the applicable ships.

In addition, the logistics capability for the motor-generator sets was reviewed to identify those repair parts with deficient or inadequate support level in the Navy supply systems' stock. Based on this review, action was initiated to procure additional parts for stock and SPCC MECH modified its formula for repair parts stock determination to increase the number of specific parts stocked.

Since January 1972, the Naval Ship Engineering Center, Mechanicsburg Division has been monitoring all 400-Hz motor-generator casualty reports. In an effort to assist SPCC MECH in its response to parts requests, NAVSEC MECHDIV took follow-up action to expedite long lead time items. They were also able to recommend the stocking of particular parts based on the number of failures noted in the casualty reports.

HARDWARE RELIABILITY

Failure or malfunction of the 400-Hz motor-generator power supply can lead to malfunction or failure of the user equipment. Since these user equipments include radars and weapons systems, a serious reduction in the ship's ability to perform its mission can occur. The reliability of the power supply must, therefore, be as high as possible.

From an analysis of NAVSEC MECHDIV casualty reports, maintenance data and Fleet reports, it became evident that there were an excessive number of failures and high maintenance times associated with particular motor-generator sets. These units were tabulated in a "Top 25 Listing" both by the number of casualties each experienced in the previous three years and by their individual Material Condition Index. This index number, normally quoted on a total equipment basis, is calculated using a formula which includes the number of casualty reports broken down by severity and the equipment downtime. The higher the index number, the poorer the equipment reliability. The listing was updated quarterly so as to identify any new problem equipments.

A detailed engineering and piece part failure analysis was then conducted by NAVSEC to determine failure patterns and possible design deficiencies. In several instances, it was apparent that the equipment must be considered obsolete. Repair parts were difficult, if not impossible, to obtain as the manufacturer was no longer in business. For these cases, replacement motor-generator sets were procured.

Several motor-generator sets appeared to have specific design deficiencies that could be corrected by modifying the existing units. The assistance of both contractors and Navy activities was engaged to develop and provide modification kits to improve the equipment reliability; each kit containing all required parts, technical manual change pages and modified APL's. Replacement of 105 motor-generator sets is currently underway as is the modification of 326 units. Figure 4 summarizes the status of the numerous actions taken to improve hardware reliability.

It is worth noting that not only did the program provide the improvement mod kits, but it also made provision for the installation and subsequent checkout of the modified units. All too often, mod kits are left to molder in the stock system for years because the funds or personnel are just not available to install them. To avoid this happening, the Naval Ship Engineering Center field activities, Naval Electronics Laboratory Center and David W. Taylor Naval Ship Research and Development Center were tasked to do mod kit installations. Where possible, engineering services were provided in contracts so that the contractor who developed the kit did the installation work. It was, thus, assured that the kits were installed as soon as possible and the avowed goal of improved reliability achieved.

In the course of equipment failure analysis, it was noted that many of the casualties occurring in water-cooled motor-generator sets could be attributed to loss of cooling water flow. With decreased or no water flow, the temperature of the motor-generator set rapidly exceeds allowable limits and, if not shutdown in time, will cause insulation and component failure. To insure that the units are not operated without adequate water flow, action has been initiated to install solenoid valves, flow switches and alarm systems to indicate zero or reduced water flow and high motor-generator set temperatures.

Action was also taken to improve the environment in which the equipment must operate. These improvements include relocation of equipment, increase in compartment ventilation, addition of duct filters and provision of battery exhaust hoods.

Attention was also given to improving the reliability of line voltage regulators (LVR's); devices external to the motor-generator sets that maintain line voltage balance where extensive single-phase loads are encountered and also assure rated voltage at the end of long cable runs. Unreliable LVR's were refurbished and major deficiencies corrected, while the LVR specification was updated to preclude the possibility of similar failures occurring on newly procured units. Concurrent with hardware improvements, tests were conducted on several ships to determine if the LVR's were actually required for particular ship configurations. The resultant data indicated that the LVR's could be removed from the Navy Tactical Data System and AN/SPG 55B systems on specific ships without any significant system degradation but with a benefit in reduction of system casualties. Action was, accordingly, taken to remove LVR's from the NTDS system on DDG 37 and CG 16 Class ships and from the 55B radar system on DDG 37, CG 16 and CG 26 Class ships.

An important consideration in preserving the reliability of the equipment is the periodic overhaul of the motor-generator sets. As an aid to the overhaul activity and to promote standardization of procedures, Technical Repair Standards (TRS's) were developed for all high population motor-generator sets. Each TRS provides examination, test, repair, maintenance and performance specifications and establishes minimum standards of acceptance.

TRAINING

Reliable equipment and logistics support can be of little value if Fleet personnel lack the training necessary to properly maintain, operate and repair the equipment. Reports from the Fleet indicated that a severe lack of training existed. Many repair personnel could not cope with the new solid-state control systems and repairs were often deferred for tender, yard or contractor personnel with a consequent increase in equipment downtime.

To remedy this situation, a Training Plans Conference was conducted and action taken to update the curriculum at Great Lakes to include all major motor-generator control systems and to establish Class "C" schools on both the east and west coasts. The first class was held at the Service School Command, San Diego, in August 1974, while classes were begun at the Fleet Training Command, Norfolk, a month later.

As an expedient until the "C" schools could become operational, urgently required training was provided by contractor personnel (see Figure 5). In addition, specially prepared audio/visual slide training presentations were developed by NAVSEC on problem motor-generator sets to assist Fleet personnel in troubleshooting the equipment. Nine such presentations have been delivered to 93 ships.

FLEET SUPPORT

Ship Assistance Teams

In the interim, until the effects of the improvements in logistics support and improved training could be felt in the Fleet, direct Fleet support was provided by means of the Ship Assistance Team (SAT) effort. Begun in January 1972 and terminated in December 1975, the SAT visited 402 ships and performed the following services:

- On-site training for ship's crews.
- Determination of equipment condition and recommendations for follow-on maintenance actions.
- Minor repairs and adjustments.
- Logistics survey.
- Tech assist on an "as required" basis.

In order to provide the SAT with knowledgeable team members, NAVSEC called upon the naval shipyards for assistance. Here again, personnel

restraints limited the number of yards that could furnish the required teams and, in the end, only five yards were able to participate in the program.

Three people were required for each team - a team leader/engineer, a mechanic and a logistic specialist. The team leader acted as liaison with the ship, conducted crew training seminars and prepared a detailed report of the SAT visit findings and recommendations. The mechanic performed minor repairs and adjustments and took part in the crew training sessions. The logistics expert conducted bin checks to determine onboard stock shortages, conducted inventory and validation of the COSAL with installed 400-Hz equipment, reviewed APL's for correctness and accuracy and assisted the crew in preparation of requisitions for shortages in parts and documentation. When, after its three day visit, the team left the ship, its crew was better trained, its equipment in better condition, and its logistics documentation and parts support better organized.

To oversee the SAT operation, the Naval Ship Engineering Center established coordinators at its Norfolk and San Diego divisions. Each coordinator performed admirably in the scheduling of SAT visits, provision of technical guidance and review and distribution of SAT reports.

Technical Manual Supplements

While the troubleshooting capabilities of Fleet personnel are primarly dependent upon the degree to which they are trained, the availability of an accurate and informative technical or service manual greatly enhances this capability. Reports from the Fleet, however, indicated that many manuals were poorly written and lacked detailed servicing information.

Never too old to learn, the NAVSEC electrical branch tore a page from the electronic community's manual. In fact, the whole manual concept - the Symbolic Integrated Maintenance Manual (SIMM) - was adapted for use as a power systems manual; the specification requirements modified to make them "fit" motor-generator sets.

The basic philosophy behind the SIMM-type manual is the presentation of schematic diagrams, troubleshooting techniques and amplifying data in a logical, stepped sequence. The standard schematic diagram with its maze of lines and often arbitrary location of components is replaced by a functional block diagram. Parts are grouped on the diagram according to their function in the circuit - voltage sensing, error detector, etc. - and assigned a unique circuit designator, while the function of each grouping is thoroughly explained in the amplifying information. The diagram is also laid out in such a manner that the signal flow progresses from left to right (except for feedback signals) across the page, enabling the reader to easily trace the various control and power signals as they are operated upon by the different circuit functional blocks (see Figure 6).

An important adjunct to the SIMM-type manual is the inclusion of a Maintenance Dependency Chart (MDC). Based on the functional block diagram, the MDC is structured so that the satisfactory operation of an event to the right is dependent upon having the proper output at the preceeding event to the left. Since the input/output values of major functional events are provided, fault isolation can be easily achieved. The output of a specific functional event is shown as dependent upon the proper input, which, in turn, depends upon the proper output from the preceeding event, etc.

The service personnel, thus, determine the last "good" indication and the first "bad" indication. The dependency structure between these two events identifies those entities that may have failed. As shown in Figure 7, the area of concern can be further narrowed until a single failed entity is located. With proper use, the MDC can take the guesswork out of troubleshooting and lead the troubleshooter quickly to the failure.

Seventeen SIMM-type technical manual supplements were developed and issued to a total of 217 ships.

APL Cross-Reference Guide

As mentioned earlier, 1200 APL's have been created to provide repair part data for 195 motor-generator systems. One number series is used for motor-generators, another for regulators, another for control panels, etc. There was no document, however, that tied them together on a motor-generator system basis. If you knew a voltage regulator APL, for example, there was no easy or direct method of determining the motor-generator with which it was used, and vice-vera.

As an aid in the identification of the APL's associated with a particluar motor-generator set, an APL cross-reference guide was prepared by NAVSEC and distributed to all ship repair and NAVSEC field activities. Based on information obtained from SPCC MECH and data gleaned from the SAT reports, this guide provides the first authoritative means of cross-referencing the major APL's that make up a motor-generaotr set (as many as five or more) with the applicable technical manual number. Through use of this guide, the 400-Hz motor-generator sets installed on a specific ship can be identified together with their population and ancillary APL's.

POWER SYSTEM INTERFACE

The adverse effects of a user equipment on the power supply precludes the use of a completely centralized 400-Hz shipboard power system. Large nonlinear and pulsating electronic equipment loads are the prime culprits of power system degradation. They cause excessive power system

modulation, introduce waveform distorting harmonics and, consequently, prohibit the operation of other user equipment on the same power source.

The usual remedy in the past has been to provide a dedicated motor-generator set to isolate the offending equipment from the rest of the 400-Hz power system. This solution has the undesirable side effects of greatly increasing the number of motor-generator sets installed on a specific ship with the attendent increase in 60-Hz power requirements and maintenance. The number of motor-generator sets installed on ships has increased steadily in recent years as more and more 400-Hz electronic equipment is installed. Today, while the typical guided missile cruiser has twelve 400-Hz motor-generator sets, the number installed has gone as high as 22; a granted extreme, but a sign of things to come if something is not done to alleviate the situation.

One approach to this problem is to filter out the harmonics caused by the user equipment. Under a NAVSEC task, the David W. Taylor Naval Ship Research and Development Center has developed passive filters up to 200-KW that effectively reduce the harmonic distortions to an acceptable level. Their use will permit greater utilization of a centralized ship's power system.

Where pulsating loads are the problem, motor-generator sets with extremely fast response times and multi-phase voltage sensing circuits have proved to be most effective. These units in a 200-KW rating are being used successfully on several guided missile cruisers in a modified central power configuration; providing power to a 48A radar as well as other ship's service loads.

So as to avoid surprises when a new load equipment is married to a power supply, a load simulator was developed by DTNSRDC/A under another NAVSEC task for performance evaluation of the power supply. The device accurately simulates high impluse, radar-type loads so that a radar power supply can be tested at the manufacturer's plant with the "radar" for compatibility prior to shipboard installation. The simulators are portable and several are available on a loan basis from DTNSRDC/A.

A prototype test procedure was developed to determine input power parameters of 400-Hz user equipment; i.e., how far can the input power vary from the norm before the load equipment malfunctions. The availability of such empirical data is most valuable where centralized power systems are under consideration.

SUMMARY

In response to Fleet reports of numerous casualties and excessive downtime of 400-Hz power systems, the Naval Ship Engineering Center developed, managed and actively progressed the DART-TYCOM 400-Hz Motor-Generator Power Systems Improvement Program. With limited funds and extremely limited personnel, NAVSEC was able to achieve the primary objective of increasing the on-line availability of 400-Hz power systems. To accomplish this, NAVSEC concentrated on five major improvement areas - logistics support, hardware reliability, training, Fleet support and power/weapons systems interface. As a direct result of this program, the Fleet is much better able to perform its intended mission.

ACKNOWLEDGEMENT

I wish to extend my appreciation to Mr. F. E. Anderson and Mr. W. J. Glod of NAVSEC who reviewed this paper.

I am indebted to the many navy activities and contractors whose knowledge and efforts were so instrumental in achieving the program goals.

SYSTEM BLOCK DIAGRAM

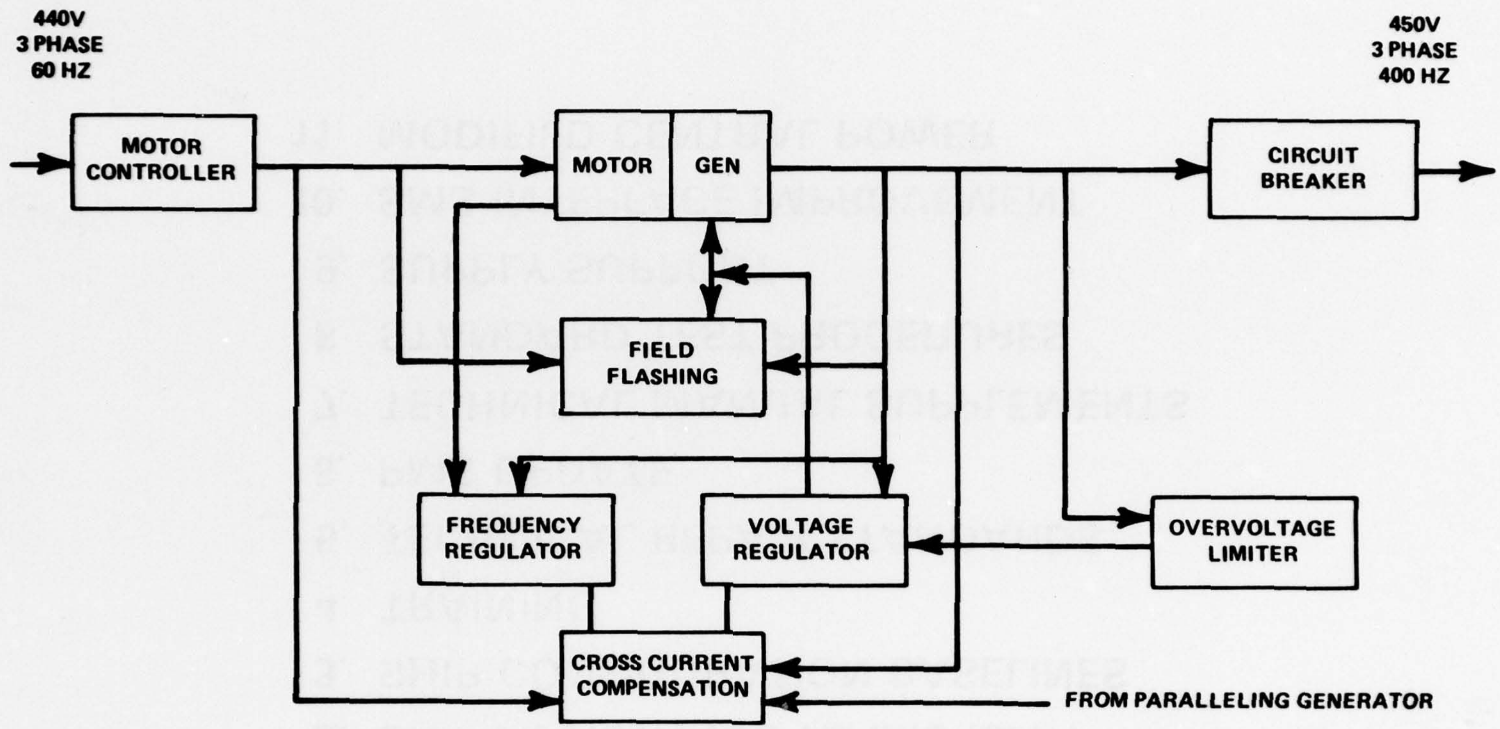


FIGURE 1

MAJOR MILESTONES

1. HIGH CASUALTY RELIABILITY FIXES
2. SHIP ASSISTANCE TEAMS (SAT)
3. SHIP CONFIGURATION BASELINES
4. TRAINING
5. TECHNICAL REPAIR STANDARDS
6. PMS UPDATE
7. TECHNICAL MANUAL SUPPLEMENTS
8. STANDARD TEST PROCEDURES
9. SUPPLY SUPPORT
10. SMS INTERFACE IMPROVEMENT
11. MODIFIED CENTRAL POWER

FIGURE 2

ACTIVITY RESPONSIBILITY DIAGRAM

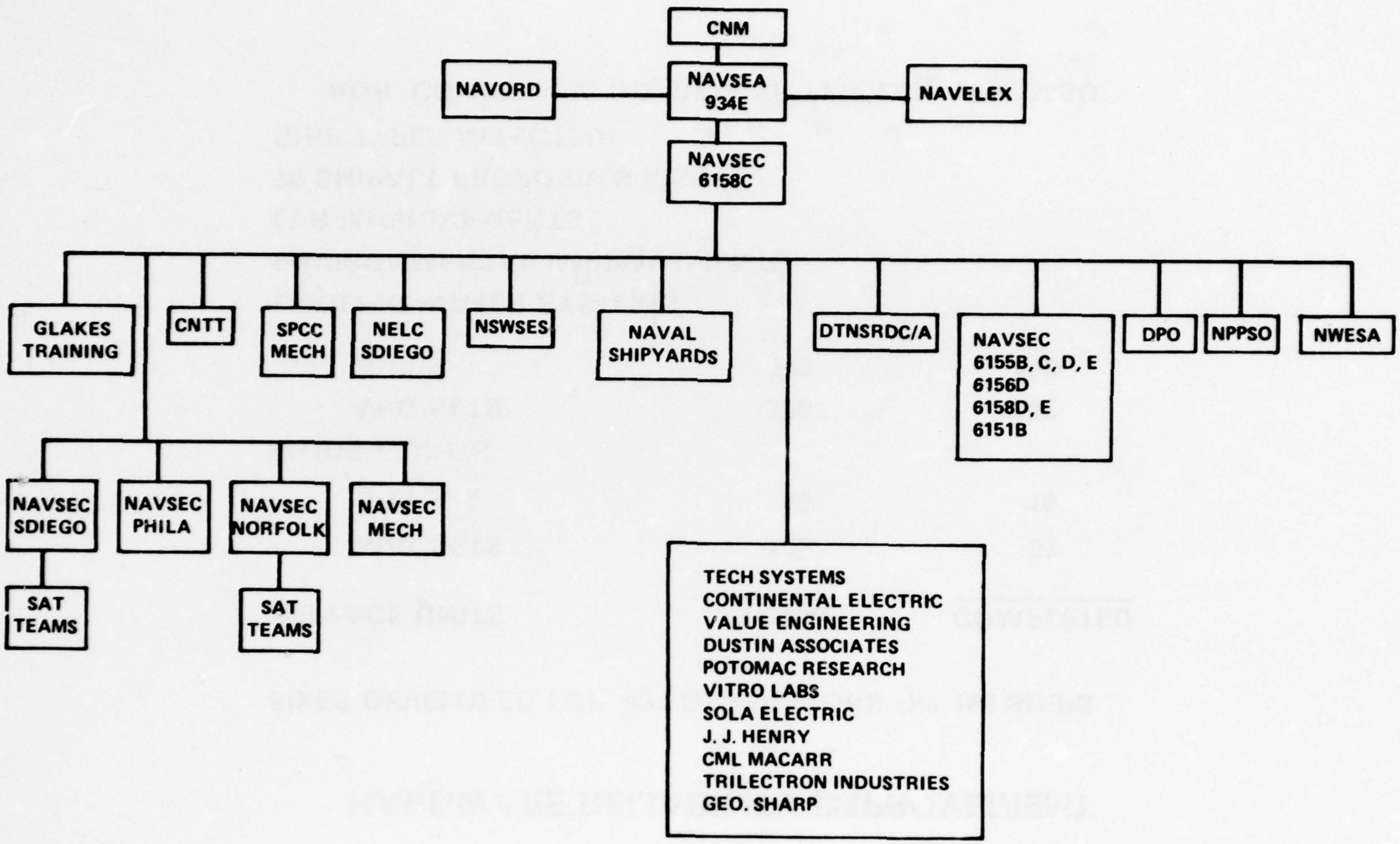


FIGURE 3

HARDWARE RELIABILITY IMPROVEMENT

FIXES DEVELOPED FOR 431 GENERATORS ON 188 SHIPS

	TOTAL	COMPLETED
REPLACE UNITS		
M/G SETS	105	51
SHIPS	45	16
MODIFY UNITS		
M/G SETS	326	242
SHIPS	143	103

COOLING WATER SYSTEMS

ENVIRONMENTAL IMPROVEMENTS

LVR IMPROVEMENTS

70 SHIPALT PROPOSALS ISSUED

SHIP TYPES AFFECTED:

AOR, CG, CGN, CV, DD, DDG, FF, FFG, LCC, LPH, MSO

FIGURE 4

TRAINING IMPROVEMENT

INTERIM

TWO WEEK COURSE FOR REPAIR PERSONNEL AT SUBIC AND YOKOSUKA.

TWO 2-WEEK COURSES ON TECH SYSTEMS MOTOR GENERATOR SETS.

SIX 4-WEEK COURSES ON MAJOR MOTOR GENERATOR SYSTEMS.

NINE AUDIO/VISUAL SLIDE PRESENTATIONS DELIVERED TO 93 SHIPS.

LONG RANGE

UPGRADED CURRICULUM AT GREAT LAKES.

ESTABLISHED "C" SCHOOLS AT FTC NORFOLK AND SSC SAN DIEGO.

FIGURE 5

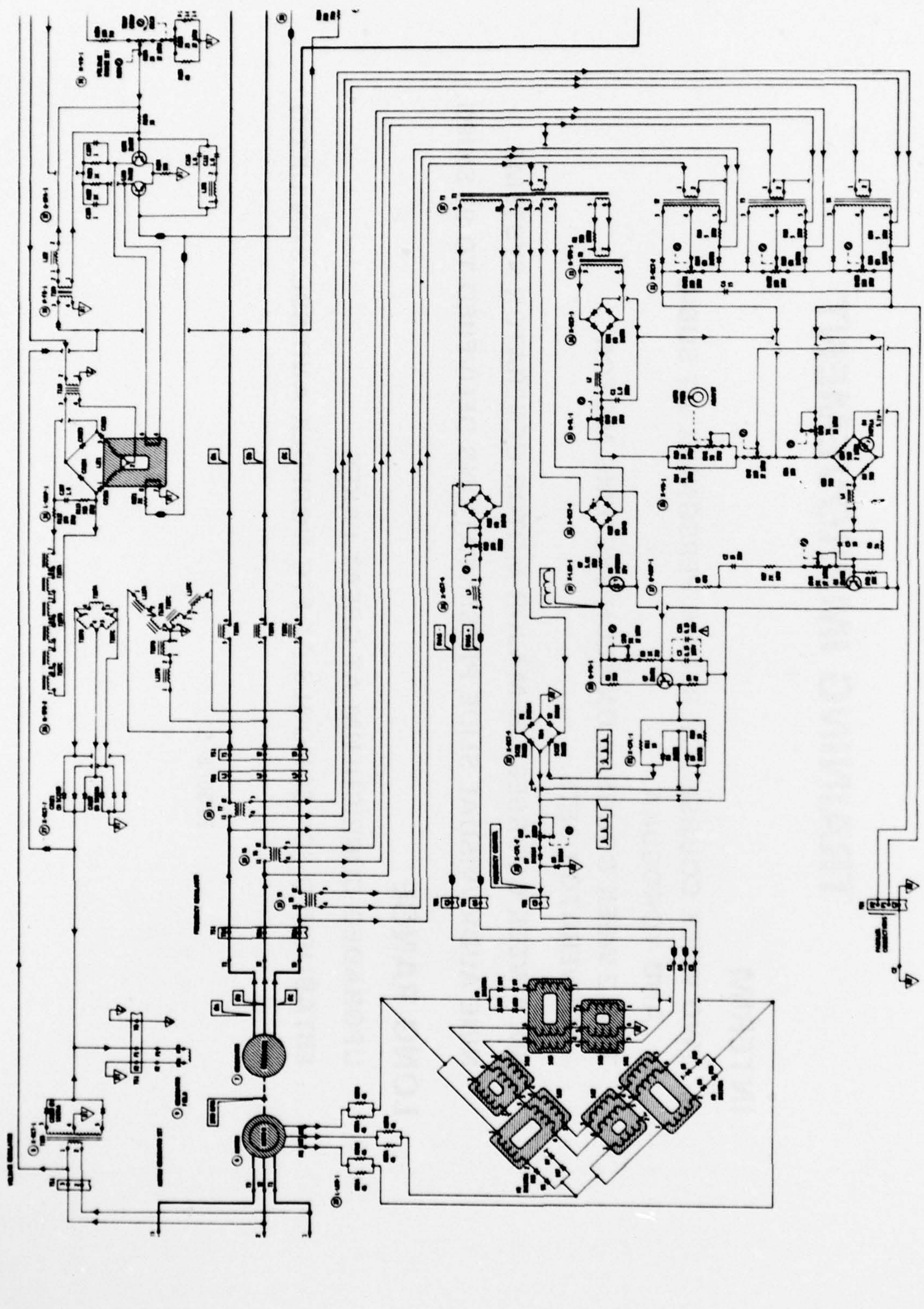
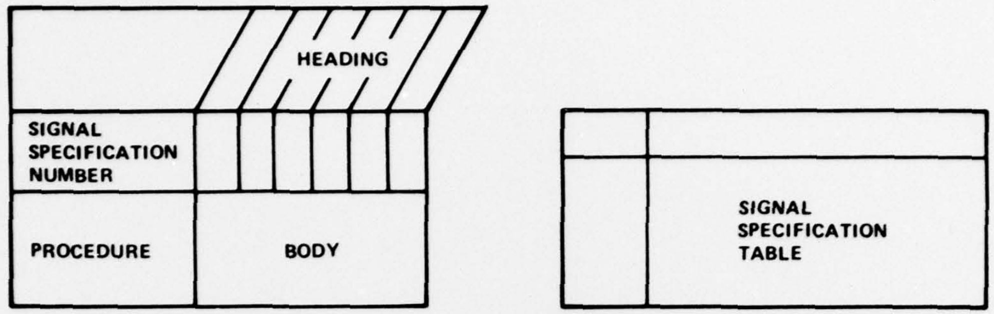


FIGURE 6

MAINTENANCE DEPENDENCY CHART

The MDC is composed of five areas: The Procedure Column, the Heading, the Signal Specification Number Row, the Body, and the Signal Specification Table.



MDC TROUBLESHOOTING TECHNIQUE

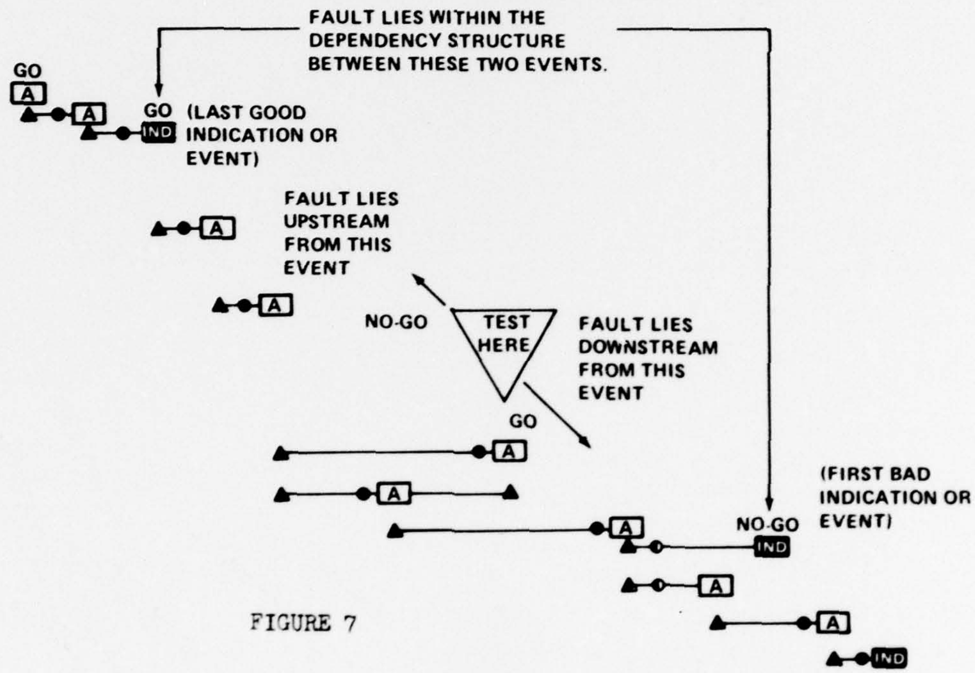


FIGURE 7